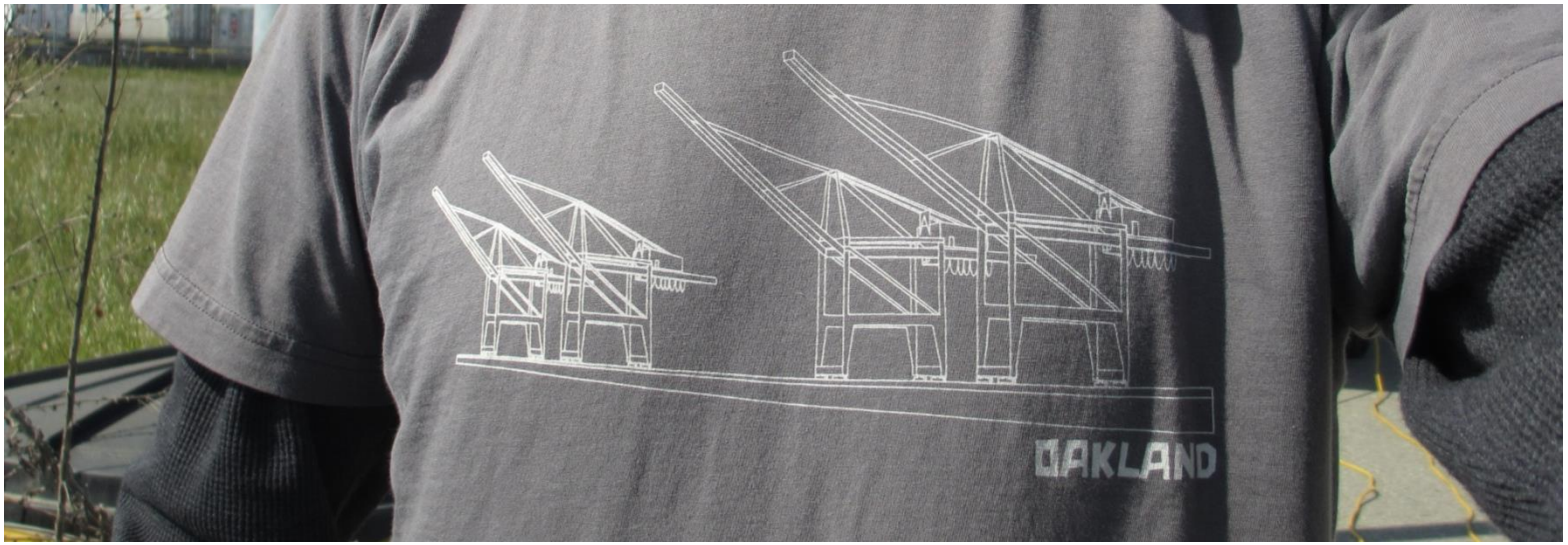
Effects of Diesel Particle Filters on Heavy-Duty Diesel Truck Emissions at the Port of Oakland



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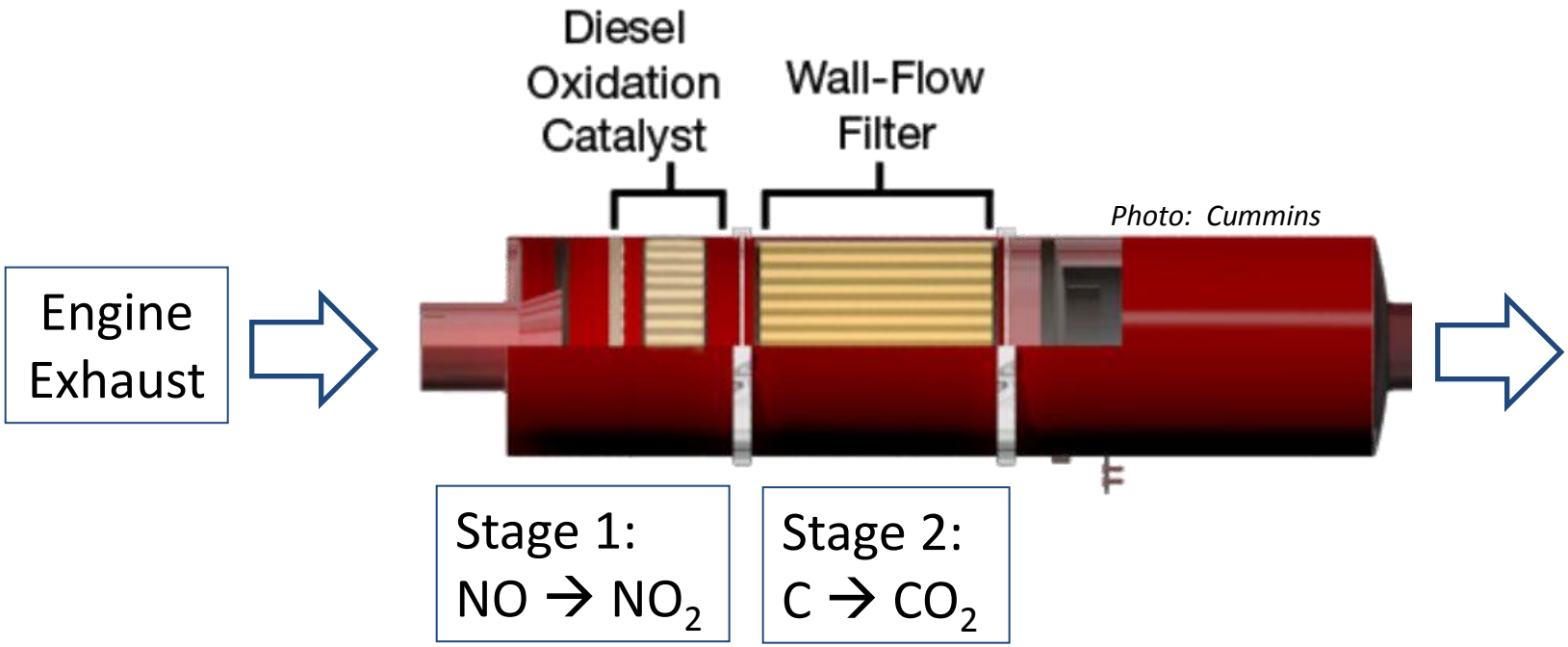
AAAR, 04 Oct 2013

Acknowledgements

- Bay Area Air Quality Management District
- California Air Resources Board

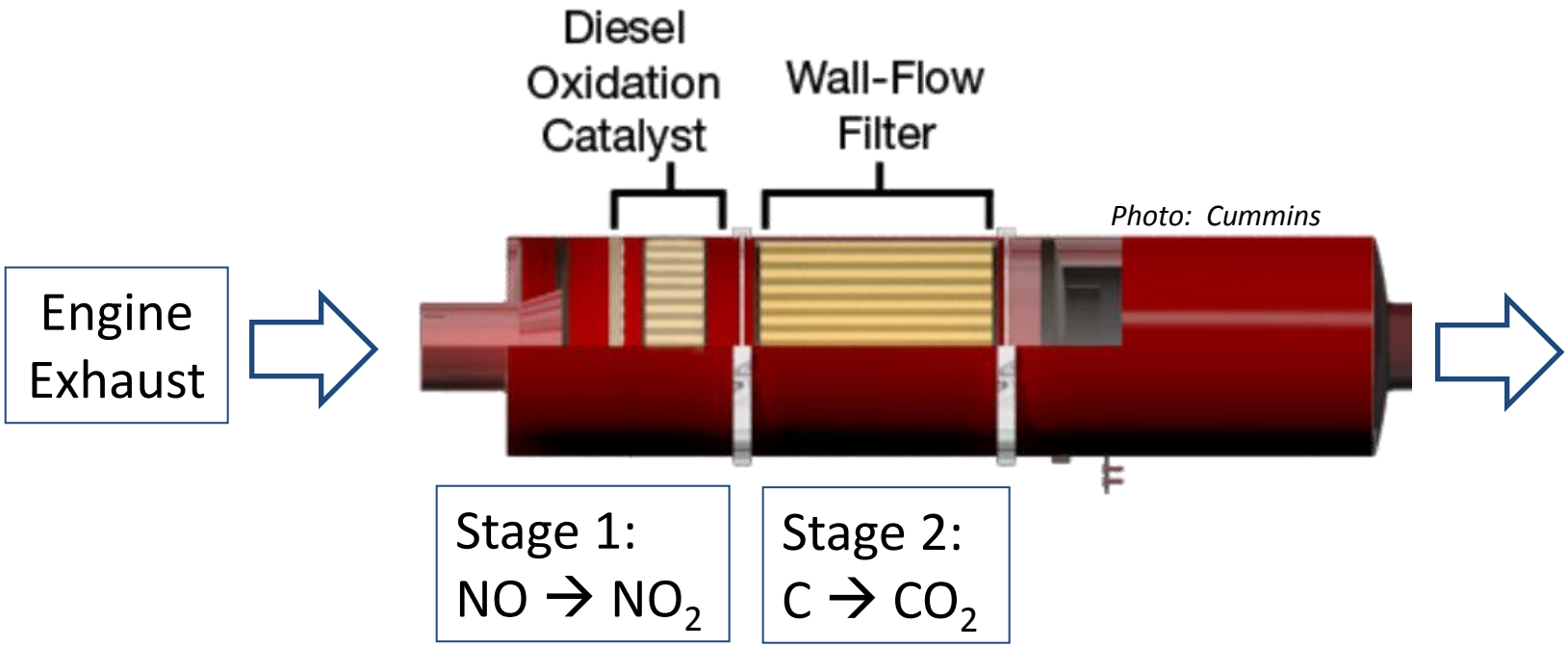
Controlling diesel PM emissions

- Diesel Particle Filters (DPFs):
  - PM control for heavy-duty diesel trucks
  - Installed downstream of engine
  - Trap and oxidize PM



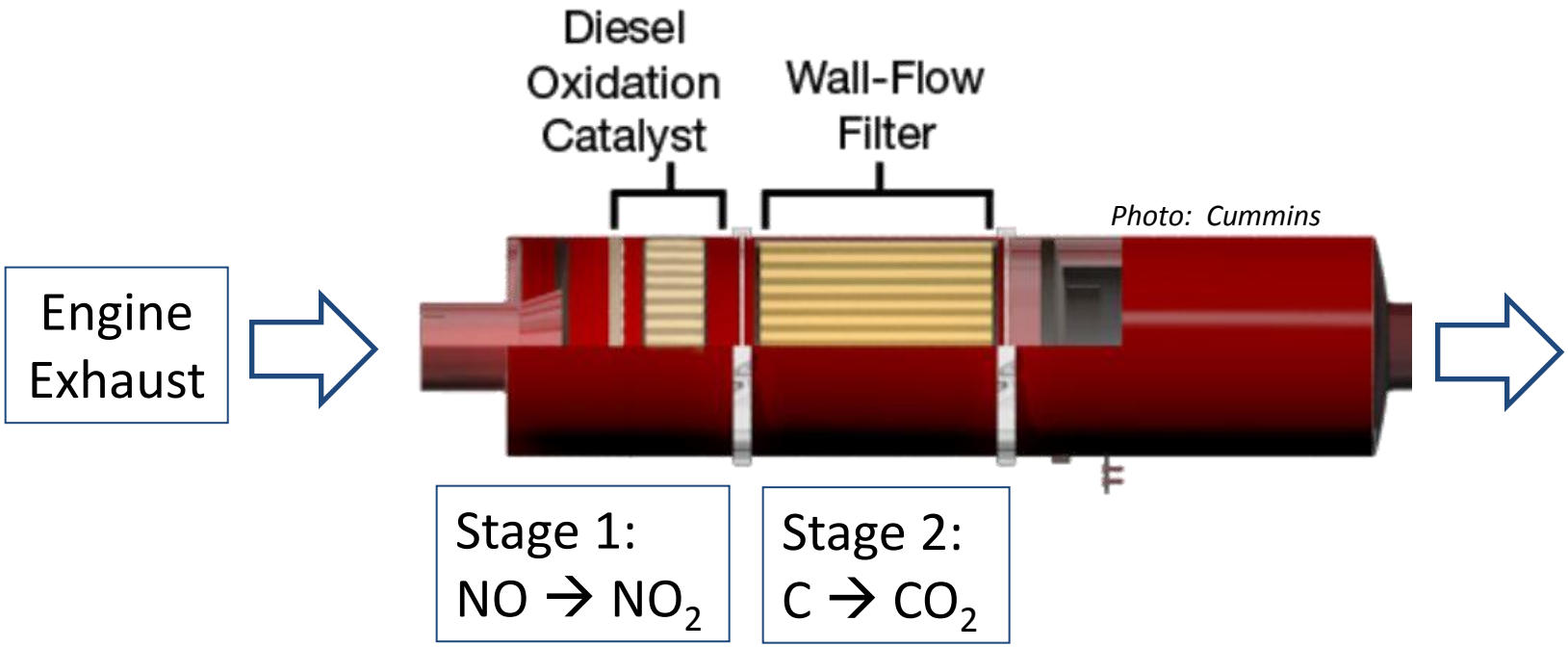
Effects of diesel particle filters (DPFs)

- Intended effects: reduce PM
- Possible side effects:
  - Increased NO_2 emissions and NO_2/NO_x ratio
  - Changes to ultrafine particle (UFP) emissions



Controlling diesel PM emissions

- Required on new diesel engines since 2007
  - Catalyst loading unregulated for new engines
- Available as retrofit for 1994-2006 engines
- Not available for older engines



Controlling truck emissions in CA

- Drayage Truck Rule
  - Targeted Port trucks before subsequent rule for statewide truck fleet
  - Retrofit and replacement program forcing accelerated PM and NO_x emissions reductions

Deadline	Engine Model Year	Requirement
Jan 2010	1993 & Older	Banned
	1994 - 2003	Retrofit/Replace
Jan 2012	2004	
Jan 2013	2005 - 2006	

Port of Oakland study

- Aim: understand how new control technologies change truck emissions
- Measurements: before rule, during rule phase in, and after all trucks required to have DPFs
  - Nov 2009 (before)
  - Nov 2011 (during)
  - Mar 2013 (after)

Port of Oakland study

- Instrumented mobile lab near Port entrance
  - Sampled exhaust plumes of passing trucks
  - Linked emissions from individual trucks to engine age and retrofit status via license plates

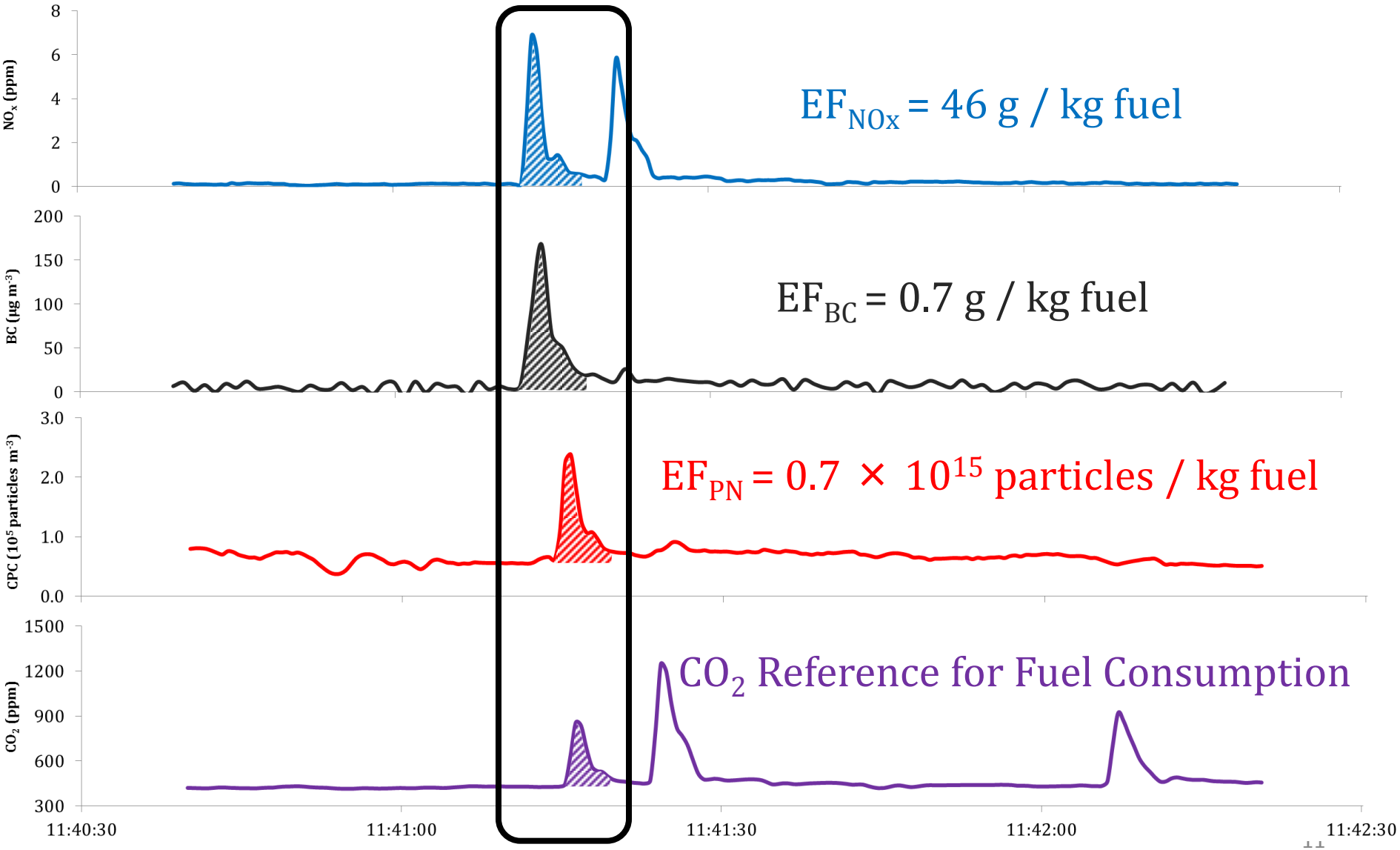
1-2 Hz measurements of truck exhaust

Pollutant	Instrument
CO_2	NDIR analyzers
NO, NO_X	Chemiluminescence
$PM_{2.5}$	DustTrak
Black Carbon (BC)	Aethalometer, Photoacoustic absorption
Ultrafine particles (UFP)	Condensation particle counters
Particle size distribution	Fast mobility particle sizer

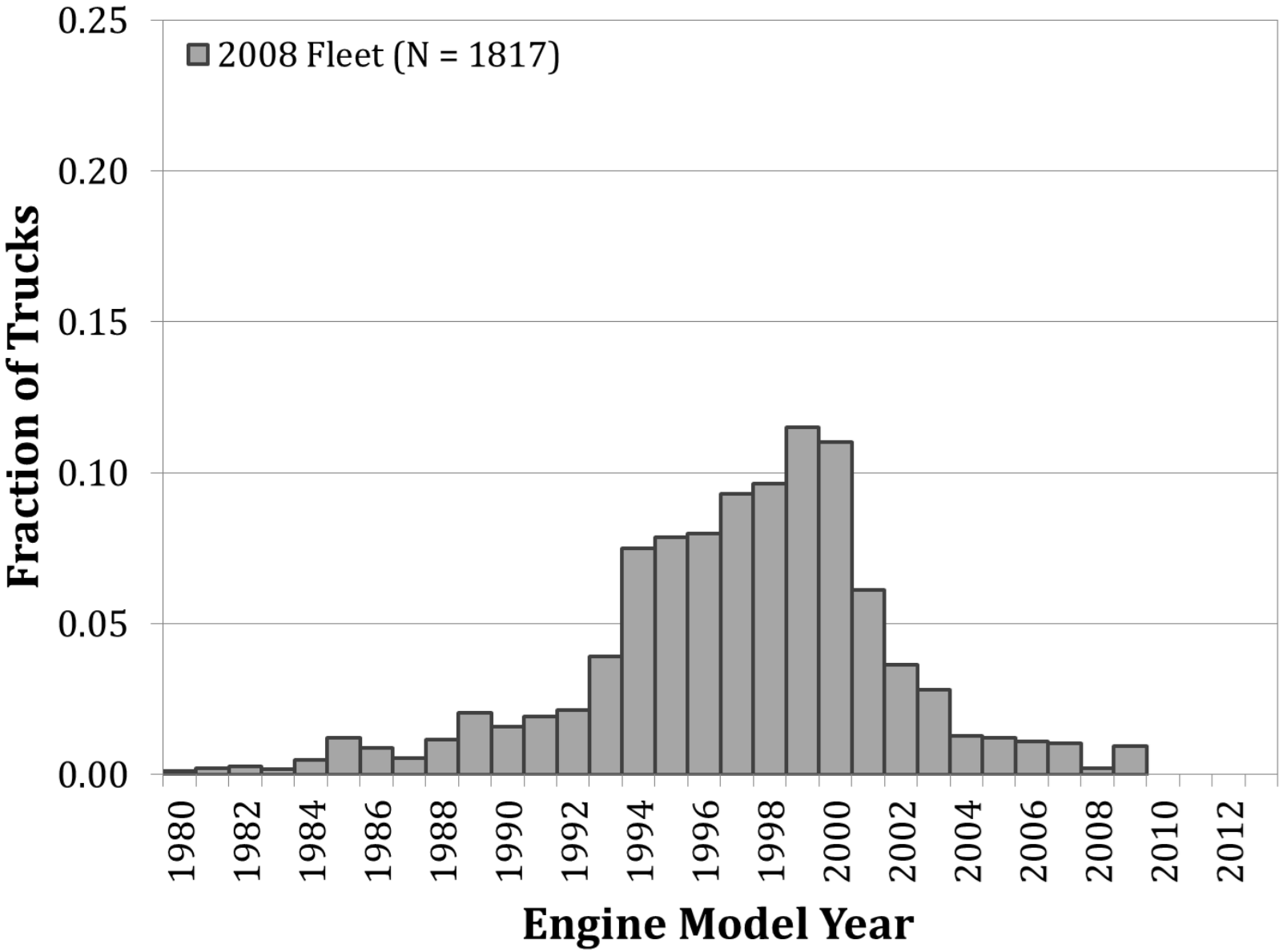
Plume capture method

- Sample line aligned with exhaust from trucks passing below for improved plume capture
- 1-2 Hz measurements catch rise and fall of pollutant peaks for each truck

Plume capture method



Evolving Port fleet age distribution



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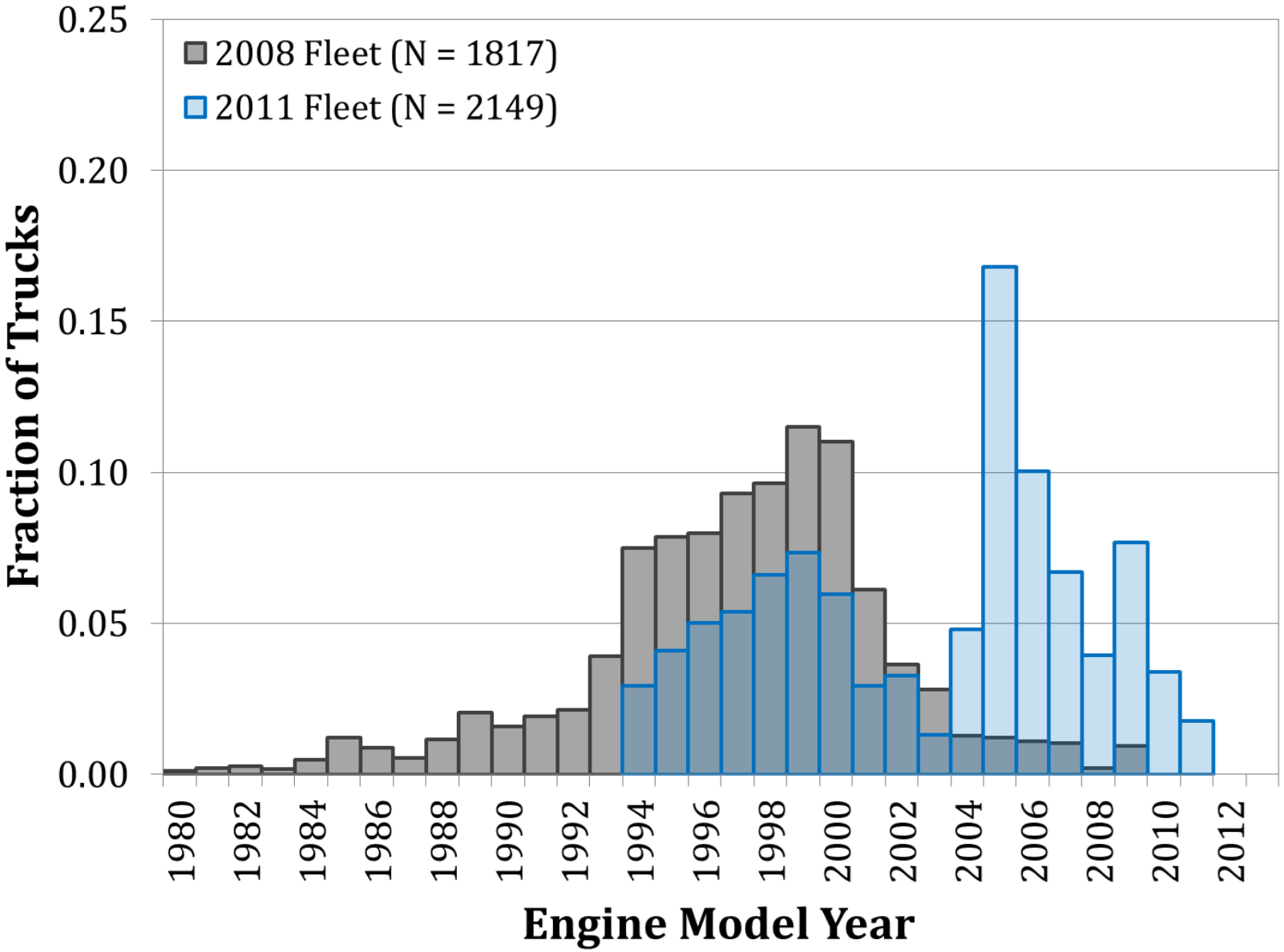
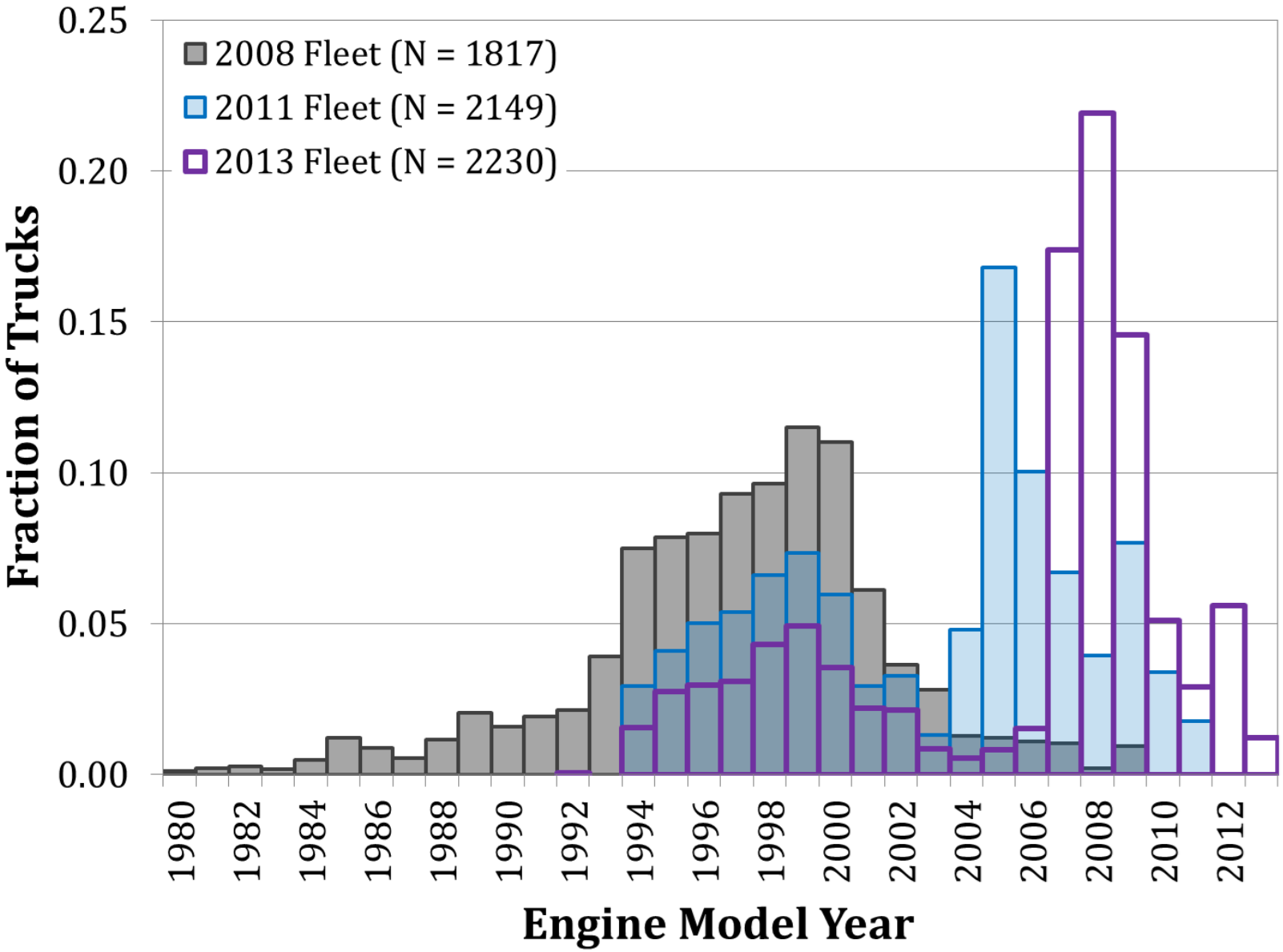
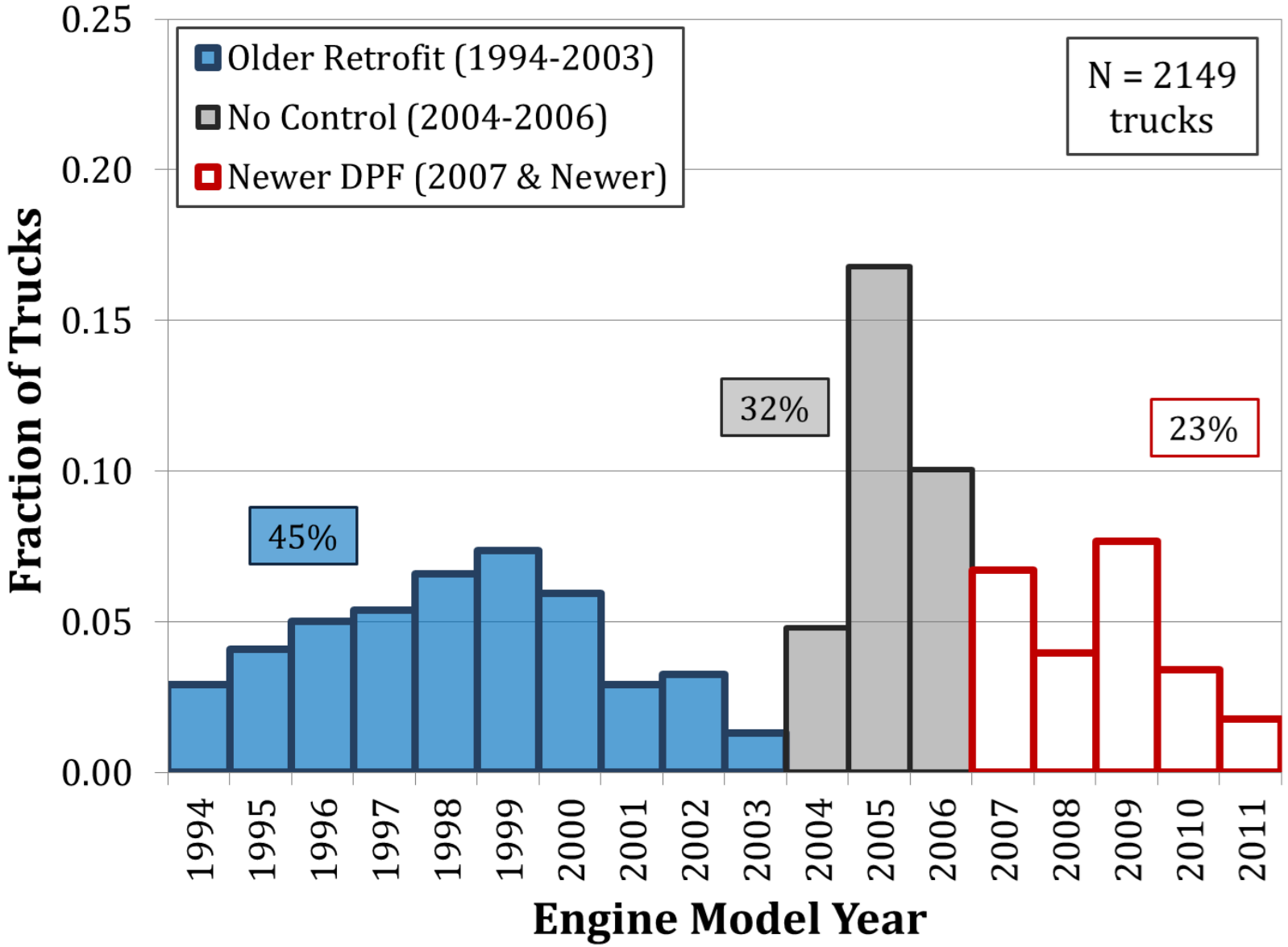


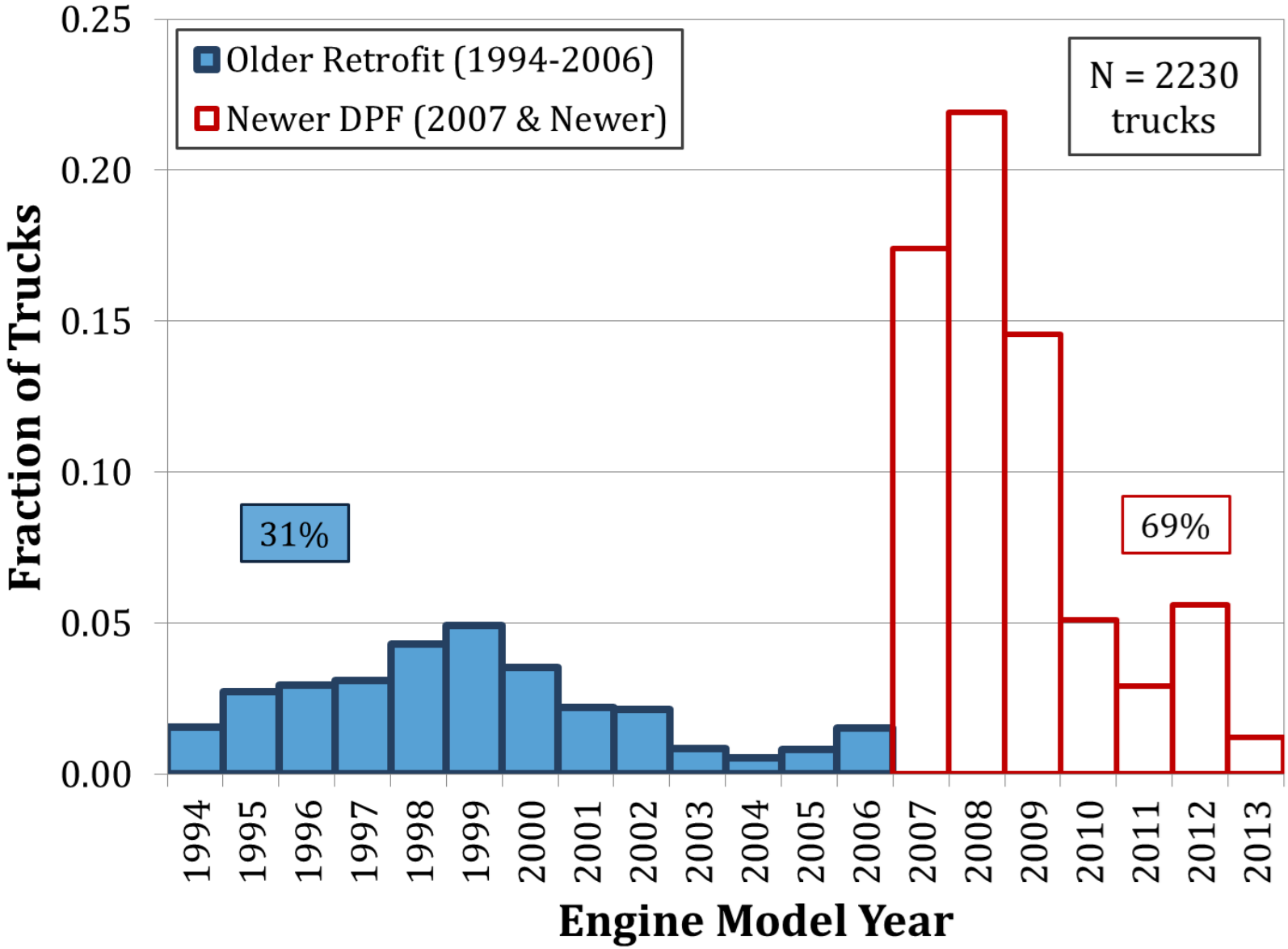
Evolving Port fleet age distribution



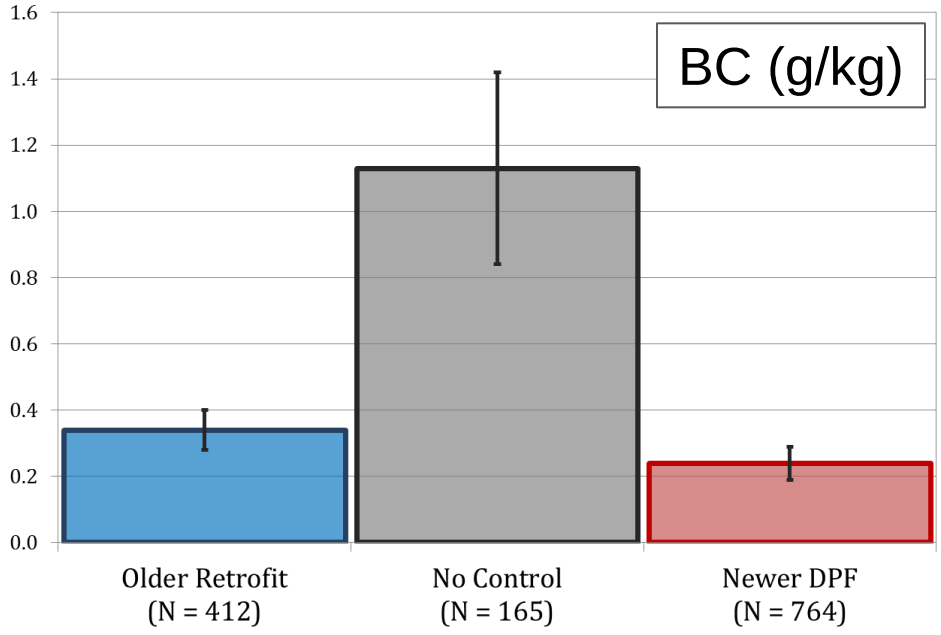
2011 truck age distribution by status

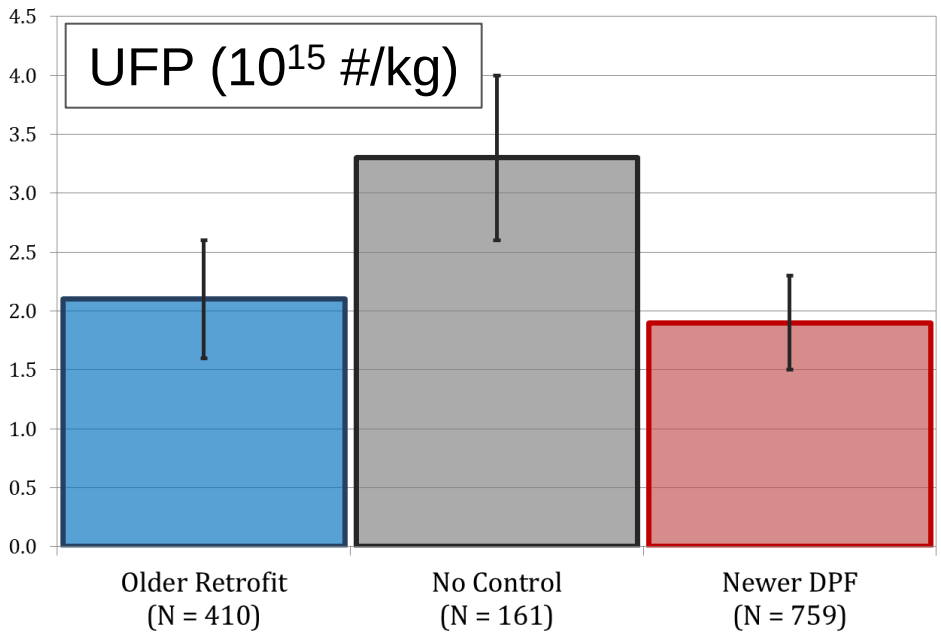


2013 truck age distribution by status



BC and UFP emissions

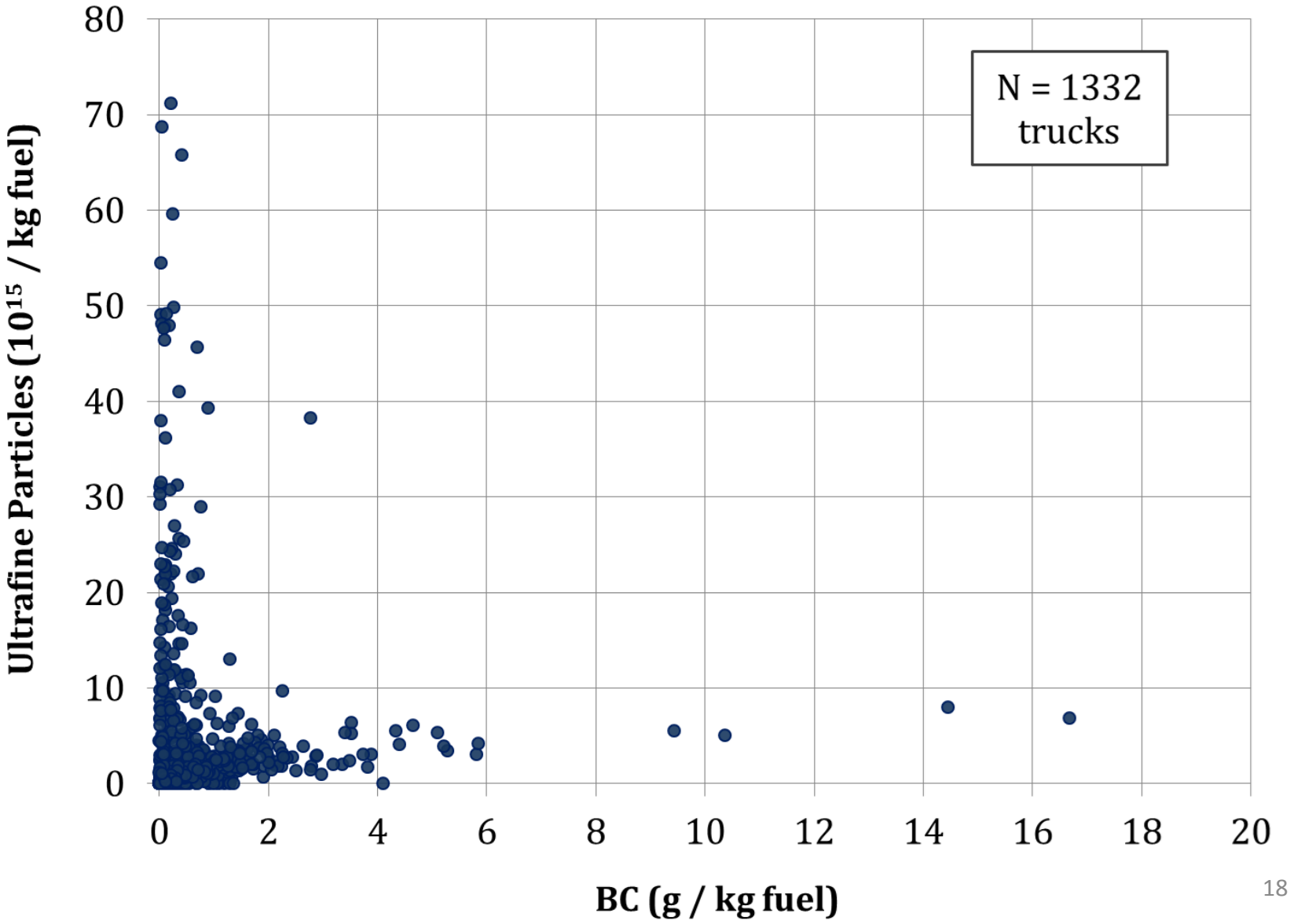




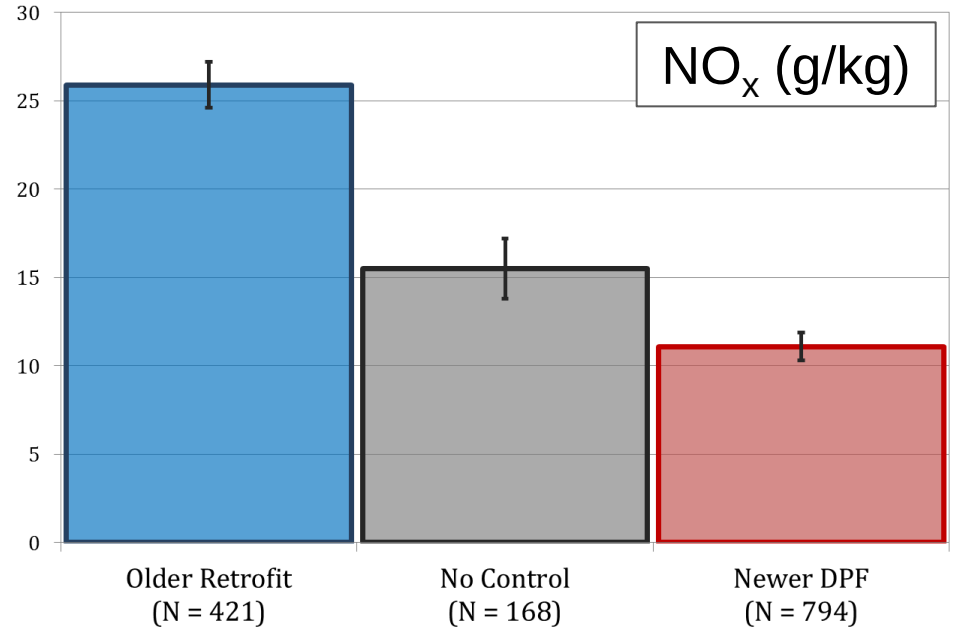
*Average emission factor ± 95% confidence interval

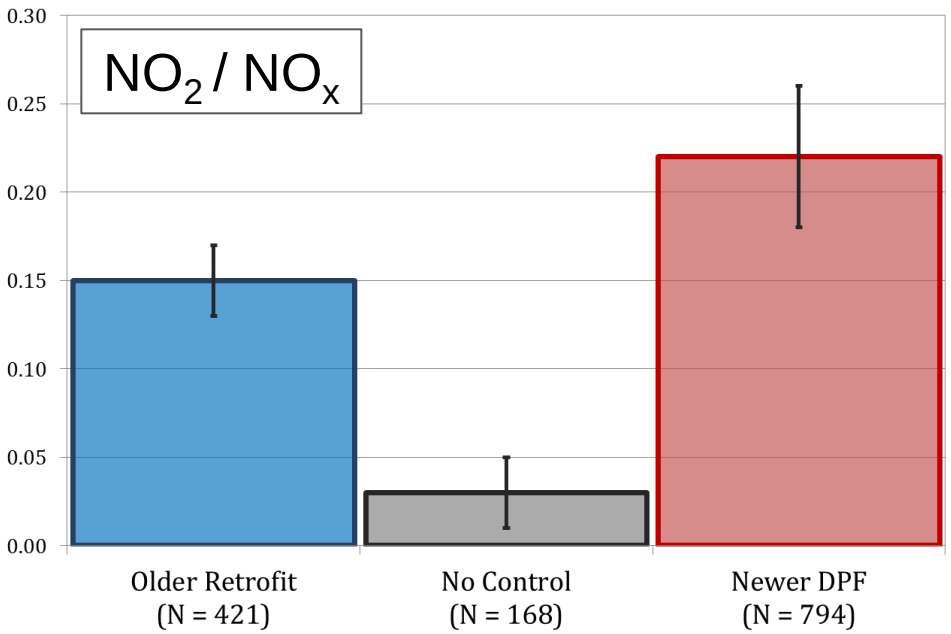
- On average, trucks without PM control emit ~4 times more BC and ~1.5 times more UFP than DPF-equipped trucks

BC and UFP emissions anti-correlated



Comparing NO_x & NO_2/NO_x emissions





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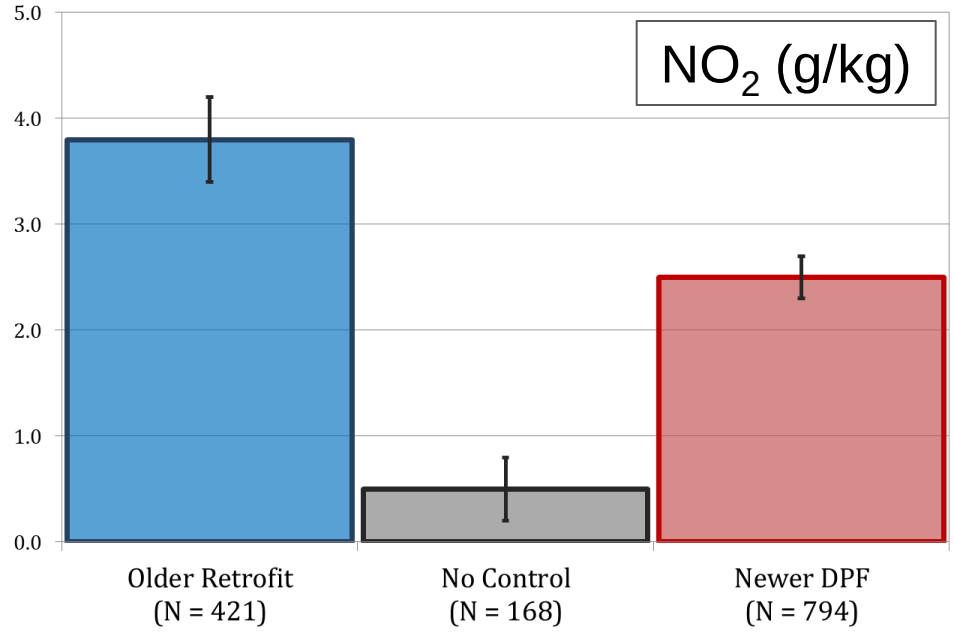
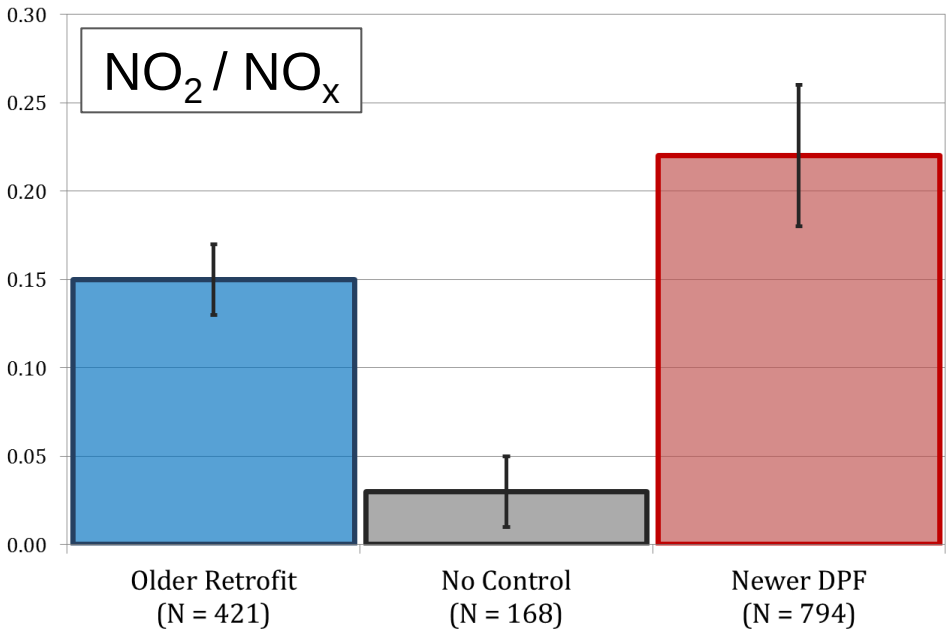
- On average, the NO_2/NO_x emission ratio is 4.5 times greater for older retrofit trucks and 7.6 times greater for newer DPF-equipped trucks than trucks without PM control

Comparing NO_x & NO_2/NO_x emissions

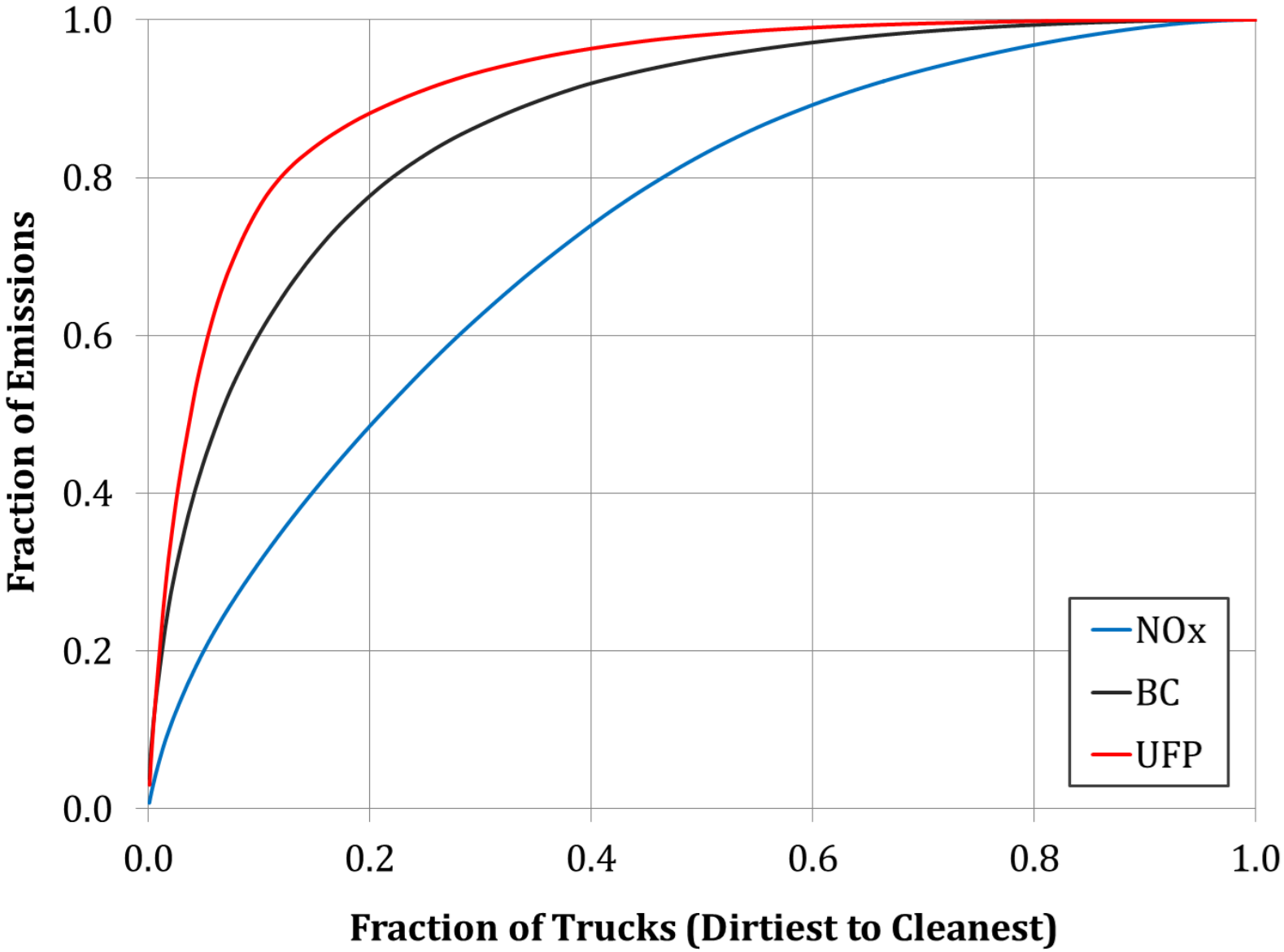




*Average emission factor ± 95% confidence interval

- On average, trucks without PM control emit 13% of the NO_2 emitted by older retrofits and 20% of the NO_2 emitted by newer DPF-equipped trucks

Emissions are skewed



Conclusions

- On average, trucks with DPFs
  - Emit 1/4 of the BC and 3/5 of the UFP emitted by trucks without PM control
  - Have much higher NO_2 emissions & NO_2/NO_x emission ratio
    - New EPA 1-hr air quality standard for NO_2 and near-road NO_2 monitoring requirement

- Further cleanup strategies would be most effective if targeting dirtiest 10% of fleet